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Livingston Rail Yard indoor air quality investigation report

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LIVINGSTON RAIL YARD
INDOOR AIR QUALITY INVESTIGATION REPORT

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Submitted to:

Montana Department of Health
and Environmental Sciences
Cogswell Building
Helena, Montana 59620

Submitted by:

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March 27, 1992

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1.0 INTRODUCTION

An indoor air quality investigation was conducted by the Burlington Northern Railroad Co. (BNRR) in residences near the Livingston Rail Yard (LRY), in Livingston, Montana. The objectives of the study are to determine whether chlorinated ethenes, migrating from the LRY via ground water and soil gas, impact the indoor air quality of nearby residences, and to provide quantitative data for the baseline public health risk assessment. Only residences with basements were sampled for this investigation. Residences with basements are considered to be "worst-case" compared to houses with only crawl spaces or houses built on slab foundations because houses with basements have a greater contact area between the house and the soil than houses with other foundation types. This report presents the investigative information collected in accordance with the Indoor Air Quality Investigation Work Plan (IAQIWP), which was approved by the Montana Department of Health and Environmental Sciences (MDHES) on January 30, 1992.

The initial sampling event was conducted from February 4 to February 14, 1992. A followup investigation was conducted between March 11 and March 13, 1992. The followup investigation was approved by the MDHES during a conference call on March 2, 1992. This report includes a description of the field activities, compilation and interpretation of the analytical results, and a preliminary health risk assessment conducted by Dr. Stephen Foster of ENSR Consulting and Engineering (ENSR).

2.0 DESCRIPTION OF FIELD ACTIVITIES

2.1 Sampling Activities

A standard operating procedure (SOP) for conducting the field sampling was developed based on the data collection requirements specified in the IAQIWP. The SOP and a schematic of the multisorbent sampler tube used to collect the samples are located in Appendix A.

2.1.1 Sampling Activities During February 1992

Indoor air samples were collected in the basements and living areas of 18 homes, along with a total of three outdoor ambient air samples. Table 1 lists all the samples collected during the February field work, along with a summary of the parameters measured during sample collection. Standard air volumes were calculated from the field measurements and used to calculate the chemical concentration values. Each sample was analyzed for tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (c-DCE), and trans-1,2-dichloroethene (t-DCE).

Figure 1.0 shows the general locations of the 18 residences and three ambient air sample locations. Five residences were sampled in the background study area. The sampled homes were randomly selected from homes with basements between "E" Street and "G" Street and between Calendar Street and Clark Street. Three residences were sampled in the northeast study area. Nine residences were sampled in the southeast study area. One of the residences originally selected to be sampled in the southeast study area was not sampled because the "basement" was actually a root cellar that was not connected to the house. The U-1 residence, which is outside the southeast study area (unclassified as to study area), was added to the list of residences at the request of the MDHES in order to maintain the total number of

Table 1: Indoor Air Quality Sampling Information for Samples Collected Between February 4 and February 14, 1992

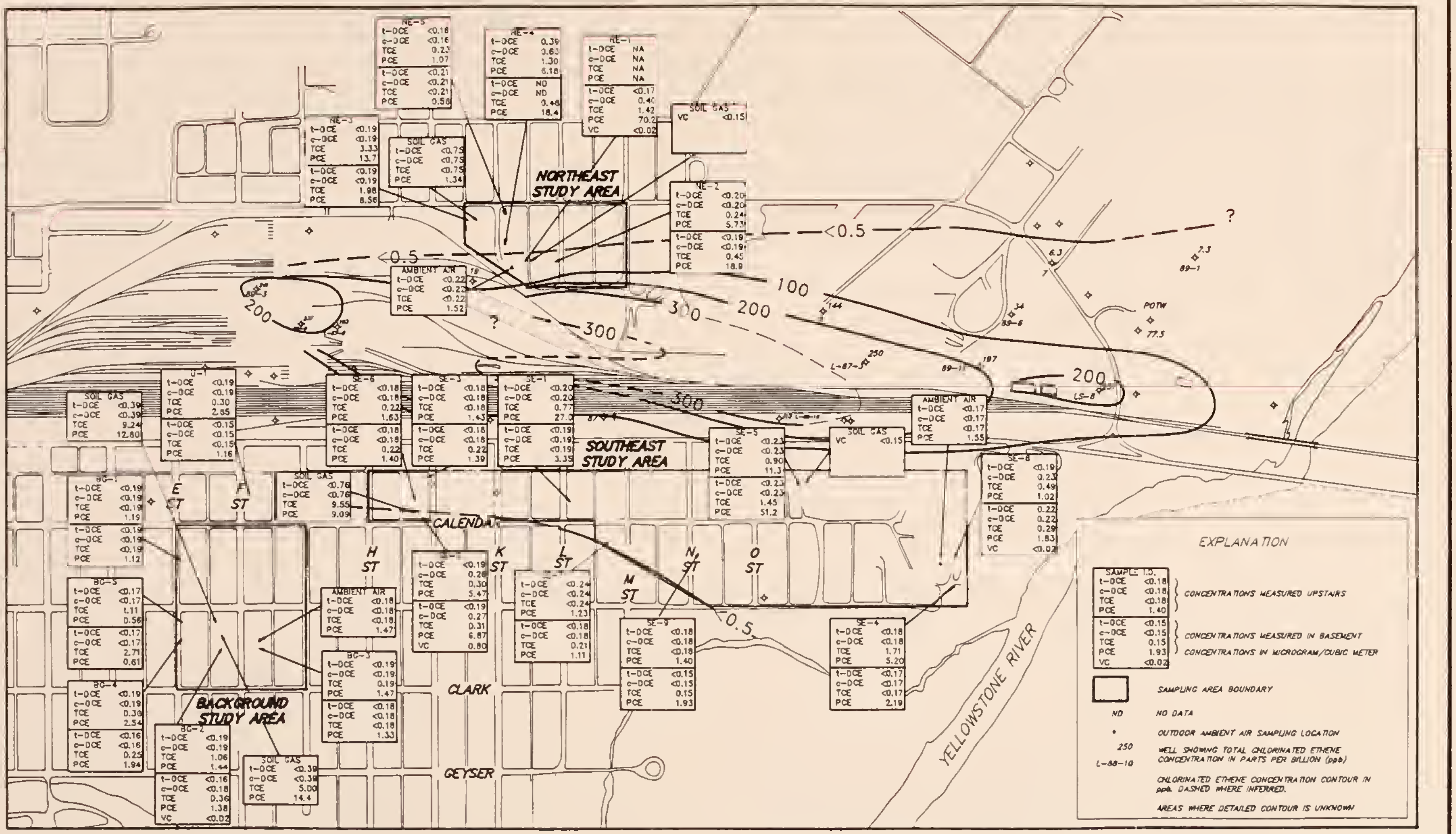
Study Area	Resident	Location	Sample Type	Date	Sampler Number	Status	Initial Temp. (F)	Final Temp. (F)	Initial Pres. In. Hg	Final Pres. In. Hg	Initial Flow Rate ml/min	Final Flow Rate ml/min	Percent Diff.	Corr. Factor	Corr. Flow Rate ml/min	Start Time	Final Time	Volume (liters)	Standard Volume (liters)
Background	BG-1	Basement	Primary	2/6/92	90	Analyzed	70	72	25.20	25.30	12.5	13	3.8	1.069	13.63	8:37	12:28	3.15	2.69
Background	BG-1	Basement	Backup	2/6/92	91	Not Analyzed	70	72	25.20	25.30	12.5	13	3.8	1.069	13.63	8:37	12:28	3.15	2.69
Background	BG-1	Basement	Blank	2/6/92	95	Not Analyzed	70		25.20										
Background	BG-1	Upstairs	Primary	2/6/92	64	Analyzed	74	74	25.20	25.30	12.5	12.5	0	1.069	13.36	9:00	12:50	3.07	2.61
Background	BG-1	Upstairs	Backup	2/6/92	63	Not Analyzed	74	74	25.20	25.30	11.5	12.5	8	1.069	12.83	9:00	12:50	2.95	2.50
Background	BG-2	Basement	Primary	2/6/92	29	Analyzed	60	63	25.20	25.30	12.9	14.9	13.4	1.058	14.71	10:20	14:22	3.56	3.09
Background	BG-2	Basement	Backup	2/6/92	59	Not Analyzed	60	63	25.20	25.30	10.3	12.1	14.9	1.058	11.85	10:20	14:22	2.87	2.49
Background	BG-2	Basement	Blank	2/6/92	39	Not Analyzed	60		25.20										
Background	BG-2	Upstairs	Primary	2/6/92	82	Analyzed	74	73	25.20	25.30	12.3	12.8	3.9	1.058	13.28	10:40	14:34	3.11	2.64
Background	BG-2	Upstairs	Backup	2/6/92	27	Not Analyzed	74	73	25.20	25.30	10.5	10.5	0	1.058	11.11	10:40	14:34	2.60	2.21
Background	BG-3	Basement	Primary	2/12/92	10	Analyzed	60	60	26.10	26.10	12.3	12.9	4.7	1.0611	13.37	8:26	12:23	3.17	2.85
Background	BG-3	Basement	Backup	2/12/92	42	Not Analyzed	60	60	26.10	26.10	11.1	12	7.5	1.0611	12.26	8:26	12:23	2.90	2.62
Background	BG-3	Upstairs	Primary	2/12/92	119	Analyzed	75	79	26.10	26.10	12.5	12.6	0.8	1.0611	13.32	8:49	12:38	3.05	2.66
Background	BG-3	Upstairs	Backup	2/12/92	121	Not Analyzed	75	79	26.10	26.10	12.1	11.4	5.8	1.0611	12.47	8:49	12:38	2.86	2.49
Background	BG-3	Outdoor	Primary	2/12/92	120	Analyzed	40	60	26.10	26.10	12.5	12.5	0	1.0611	13.26	9:12	12:55	2.96	2.72
Background	BG-3	Outdoor	Backup	2/12/92	118	Not Analyzed	40	60	26.10	26.10	10.5	10.5	0	1.0611	11.14	9:12	12:55	2.48	2.28
Background	BG-3	Outdoor	Blank	2/12/92	36	Analyzed	40		26.10										
Background	BG-4	Basement	Primary	2/11/92	041-N	Analyzed	70	70	26.10	26.10	13.7	13.6	0.7	1.069	14.59	10:37	14:41	3.56	3.15
Background	BG-4	Basement	Backup	2/11/92	56	Not Analyzed	70	70	26.10	26.10	9.7	9.3	4.1	1.069	10.16	10:37	14:41	2.48	2.19
Background	BG-4	Basement	Blank	2/11/92	73	Not Analyzed	70		26.10										
Background	BG-4	Upstairs	Primary	2/11/92	127-N	Analyzed	74	73	26.10	26.10	12.3	11	10.6	1.069	12.45	10:55	14:56	3.00	2.64
Background	BG-4	Upstairs	Backup	2/11/92	125	Not Analyzed	74	73	26.10	26.10	7.5	6.8	9.3	1.069	7.64	10:55	14:56	1.84	1.62
Background	BG-5	Basement	Primary	2/11/92	50	Analyzed	69	69	26.10	26.10	12.5	13	3.8	1.0611	13.53	10:13	14:20	3.34	2.96
Background	BG-5	Basement	Backup	2/11/92	65	Not Analyzed	69	69	26.10	26.10	9.8	9.5	3.1	1.0611	10.24	10:13	14:20	2.53	2.24
Background	BG-5	Basement	Blank	2/11/92	45	Not Analyzed	69		26.10										
Background	BG-5	Upstairs	Primary	2/11/92	32	Analyzed	72	71	26.10	26.10	12.5	12.8	2.3	1.0611	13.42	10:35	14:38	3.26	2.87
Background	BG-5	Upstairs	Backup	2/11/92	9	Not Analyzed	72	71	26.10	26.10	8.5	8	5.9	1.0611	8.75	10:35	14:38	2.13	1.87
Northeast	NE-1	Basement	Primary	2/5/92	85	Analyzed	63	59	25.25	25.25	12.5	13.5	7.4	1.069	13.9	8:00	12:01	3.35	2.91
Northeast	NE-1	Basement	Backup	2/5/92	86	Not Analyzed	63	59	25.25	25.25	10.5	10.6	0.9	1.069	11.28	8:00	12:01	2.72	2.36
Northeast	NE-1	Basement	Blank	2/5/92	88	Not Analyzed	63		25.25										
Northeast	NE-1	Upstairs		2/5/92	15	Invalid	70	75	25.25	25.25	12.5	20.5	39	1.069	17.64	8:15	12:08	4.11	3.50
Northeast	NE-1	Upstairs		2/5/92	84	Invalid	70	75	25.25	25.25	12.2	18.6	34.4	1.069	16.46	8:15	12:08	3.84	3.26
Northeast	NE-1	Basement	Primary	2/14/92	043-N	Analyzed	64	65	25.70	25.70	13.6	13.5	0.7	1.0611	14.38	8:13	12:12	3.44	3.02
Northeast	NE-1	Basement		2/14/92	046-N	Invalid	64	65	25.70	25.70	6.9	6.7	2.9	1.0611	7.22	8:13	12:12	1.72	1.52
Northeast	NE-1	Basement	Blank	2/14/92	035-N	Analyzed	64		25.70										
Northeast	NE-1	Upstairs		2/14/92	122-N	Invalid	72	67	25.70	25.70	13.5	14	3.6	1.0611	14.59	8:27	12:25	3.47	3.02
Northeast	NE-1	Upstairs		2/14/92	123-N	Invalid	72	67	25.70	25.70	10.9	11	0.9	1.0611	11.62	8:27	12:25	2.77	2.41
Northeast	NE-1	Outdoor	Primary	2/14/92	021-N	Analyzed	36	48	25.70	25.70	9.2	10.2	9.8	1.0611	10.29	8:38	12:34	2.43	2.23

Table 1: Indoor Air Quality Sampling Information for Samples Collected Between February 4 and February 14, 1992

Study Area	Resident	Location	Sample Type	Date	Sampler Number	Status	Initial Temp. (F)	Final Temp. (F)	Initial Pres. In. Hg	Final Pres. In. Hg	Initial Flow Rate ml/min	Final Flow Rate ml/min	Percent Diff.	Corr. Factor	Corr. Flow Rate ml/min	Start Time	Final Time	Volume (liters)	Standard Volume (liters)
Northeast	NE-1	Outdoor	Backup	2/14/92	049-N	Not Analyzed	36	48	25.70	25.70	9.2	11	16.4	1.0611	10.72	8:38	12:34	2.53	2.32
Northeast	NE-1	Outdoor	Blank	2/14/92	126-N	Used Before	36		25.70										
Northeast	NE-2	Basement	Primary	2/4/92	5	Analyzed	44	51	25.40	25.40	12.3	12.6	2.4	1.058	13.17	8:40	12:27	2.99	2.69
Northeast	NE-2	Basement	Duplicate	2/4/92	89	Analyzed	44	51	25.40	25.40	12.2	11.1	9	1.058	12.33	8:30	12:27	2.92	2.62
Northeast	NE-2	Basement	Blank	2/4/92	20	Analyzed	44		25.40										
Northeast	NE-2	Upstairs	Primary	2/4/92	43	Analyzed	51	63	25.40	25.40	12.5	12.5	0	1.058	13.23	9:05	12:38	2.82	2.48
Northeast	NE-2	Upstairs	Backup	2/4/92	11	Not Analyzed	51	63	25.40	25.40	6	6	0	1.058	6.35	9:05	12:38	1.35	1.19
Northeast	NE-3	Basement	Primary	2/5/92	51	Analyzed	70	70	25.25	25.15	12.5	12.5	0	1.069	13.36	12:58	16:49	3.09	2.63
Northeast	NE-3	Basement	Backup	2/5/92	54	Not Analyzed	70	70	25.25	25.15	12.5	13	3.8	1.069	13.63	12:58	16:49	3.15	2.69
Northeast	NE-3	Basement	Blank	2/5/92	16	Not Analyzed	70		25.25										
Northeast	NE-3	Upstairs	Primary	2/5/92	83	Analyzed	74	80	25.25	25.15	12.5	13.5	7.4	1.069	13.9	13:10	16:58	3.17	2.67
Northeast	NE-3	Upstairs	Backup	2/5/92	87	Not Analyzed	74	80	25.25	25.15	13.8	17.5	21.1	1.069	16.73	13:10	16:58	3.81	3.21
Southeast	SE-1	Basement	Primary	2/5/92	104	Analyzed	58	61	25.25	25.15	12.4	12	3.2	1.058	12.91	13:20	17:19	3.08	2.69
Southeast	SE-1	Basement	Backup	2/5/92	99	Not Analyzed	58	61	25.25	25.15	9	8.8	2.2	1.058	9.42	13:20	17:19	2.25	1.96
Southeast	SE-1	Basement	Blank	2/5/92	103	Not Analyzed	58		25.25										
Southeast	SE-1	Upstairs	Primary	2/5/92	93	Analyzed	73	73	25.25	25.15	12.3	12.3	0	1.058	13.01	13:45	17:30	2.93	2.48
Southeast	SE-1	Upstairs	Duplicate	2/5/92	102	Analyzed	73	73	25.25	25.15	9.4	9.4	0	1.058	9.95	13:45	17:30	2.24	1.90
Southeast	SE-2	Basement		2/5/92	98	Invalid	72	72	25.25	25.25	13.7	7.2	47.4	1.058	11.06	8:23	12:15	2.57	2.19
Southeast	SE-2	Basement		2/5/92	100	Invalid	72	72	25.25	25.25	8.5	5	41.2	1.058	7.14	8:23	12:15	1.66	1.41
Southeast	SE-2	Basement	Blank	2/5/92	94	Invalid	72		25.25										
Southeast	SE-2	Upstairs		2/5/92	97	Invalid	70	70.5	25.25	25.25	10	?		1.058					
Southeast	SE-2	Upstairs		2/5/92	101	Invalid	70	70.5	25.25	25.25	12.6	?		1.058					
Southeast	SE-2	Basement	Primary	2/13/92	058-N	Analyzed	74	76	25.65	25.65	12.5	12.5	0	1.0611	13.26	13:08	17:03	3.12	2.68
Southeast	SE-2	Basement	Duplicate	2/13/92	014-N	Analyzed	74	76	25.65	25.65	11.9	12.5	4.8	1.0611	12.95	13:08	17:03	3.04	2.62
Southeast	SE-2	Basement	Blank	2/13/92	019-N	Not Analyzed	74		25.65										
Southeast	SE-2	Upstairs	Primary	2/13/92	082-N	Analyzed	70	73	25.65	25.65	12.6	12.8	1.6	1.0611	13.48	13:25	17:14	3.09	2.67
Southeast	SE-2	Upstairs	Backup	2/13/92	029-N	Not Analyzed	70	73	25.65	25.65	10	10.2	2	1.0611	10.72	13:25	17:14	2.45	2.13
Southeast	SE-3	Basement	Primary	2/6/92	66	Analyzed	63	63	25.30	25.30	12.5	12	4	1.069	13.09	13:20	17:20	3.14	2.73
Southeast	SE-3	Basement	Backup	2/6/92	57	Not Analyzed	63	63	25.30	25.30	11.5	12	4.2	1.069	12.56	13:20	17:20	3.01	2.62
Southeast	SE-3	Basement	Blank	2/6/92	12	Not Analyzed	63		25.30										
Southeast	SE-3	Upstairs	Primary	2/6/92	52	Analyzed	68	70	25.30	25.30	12.8	12	6.3	1.069	13.26	13:40	17:40	3.18	2.73
Southeast	SE-3	Upstairs	Backup	2/6/92	6	Not Analyzed	68	70	25.30	25.30	12.2	13.5	9.6	1.069	13.74	13:40	17:40	3.30	2.83
Southeast	SE-4	Basement		2/4/92	49	Invalid													
Southeast	SE-4	Basement		2/4/92	40	Invalid													
Southeast	SE-4	Basement	Blank	2/4/92	21	Invalid													
Southeast	SE-4	Upstairs	Primary	2/4/92	58	Analyzed	76	80	25.40	25.40	12.6	12.3	2.4	1.069	13.31	13:40	17:40	3.19	2.71
Southeast	SE-4	Upstairs	Backup	2/4/92	17	Not Analyzed	76	80	25.40	25.40	14.5	12.5	13.8	1.069	14.43	13:40	17:40	3.46	2.93
Southeast	SE-4	Basement	Primary	2/13/92	015-N	Analyzed	55	58	26.10	26.30	12.2	12.8	4.7	1.069	13.36	14:37	18:37	3.21	2.92

Table 1: Indoor Air Quality Sampling Information for Samples Collected Between February 4 and February 14, 1992

Study Area	Resident	Location	Sample Type	Date	Sampler Number	Status	Initial Temp (F)	Final Temp (F)	Initial Pres. in. Hg	Final Pres. in. Hg	Initial Flow Rate ml/min	Final Flow Rate ml/min	Percent Diff	Corr. Factor	Corr. Flow Rate ml/min	Start Time	Final Time	Volume (liters)	Standard Volume (liters)
Southeast	SE-4	Basement	Backup	2/13/92	101-N	Not Analyzed	55	58	26.10	26.30	13.1	14.8	11.5	1.069	14.91	14:37	18:37	3.58	3.26
Southeast	SE-4	Basement	Blank	2/13/92	084-N	Not Analyzed	55		26.10										
Southeast	SE-4	Upstairs	Primary	2/13/92	094-N	Analyzed	70	74	26.10	26.30	12.5	11.8	5.6	1.069	12.99	14:12	18:17	3.18	2.81
Southeast	SE-4	Upstairs	Backup	2/13/92	087-N	Not Analyzed	70	74	26.10	26.30	11	11.9	7.6	1.069	12.24	14:12	18:17	3.00	2.65
Southeast	SE-5	Basement	Primary	2/11/92	001-N	Analyzed	63	65	26.10	26.10	13.8	14.4	4.2	1.069	15.07	13:40	17:34	3.53	3.15
Southeast	SE-5	Basement	Duplicate	2/11/92	030-N	Analyzed	63	65	26.10	26.10	8.9	10.2	12.7	1.069	10.21	13:40	17:34	2.39	2.14
Southeast	SE-5	Basement	Blank	2/11/92	002-N	Analyzed	63		26.10										
Southeast	SE-5	Upstairs	Primary	2/11/92	117-N	Analyzed	78	75	26.10	26.10	11.2	10	10.7	1.069	11.33	14:03	17:47	2.54	2.22
Southeast	SE-5	Upstairs	Backup	2/11/92	116-N	Not Analyzed	78	75	26.10	26.10	12.5	10	20	1.069	12.03	14:03	17:47	2.69	2.35
Southeast	SE-6	Basement	Primary	2/11/92	47	Analyzed	70	71	26.10	26.10	12.5	11.2	10.4	1.0611	12.57	13:54	18:00	3.09	2.73
Southeast	SE-6	Basement	Backup	2/11/92	31	Not Analyzed	70	71	26.10	26.10	10	9.8	2	1.0611	10.5	13:54	18:00	2.58	2.28
Southeast	SE-6	Upstairs	Primary	2/11/92	26	Analyzed	72	73	26.10	26.10	12.5	12.5	0	1.0611	13.26	14:16	18:13	3.14	2.77
Southeast	SE-6	Upstairs	Backup	2/11/92	25	Not Analyzed	72	73	26.10	26.10	11.9	11.5	3.4	1.0611	12.41	14:16	18:13	2.94	2.59
Southeast	SE-6	Upstairs	Blank	2/11/92	33	Not Analyzed	72		26.10										
Southeast	SE-7	Basement	Primary	2/6/92	19	Analyzed	60	65	25.20	25.15	12.9	12.8	0.8	1.058	13.6	13:52	17:50	3.24	2.80
Southeast	SE-7	Basement	Backup	2/6/92	62	Not Analyzed	60	65	25.20	25.15	8.8	9.1	3.3	1.058	9.47	13:52	17:50	2.25	1.95
Southeast	SE-7	Basement	Blank	2/6/92	68	Not Analyzed	60		25.20										
Southeast	SE-7	Upstairs	Primary	2/6/92	14	Analyzed	70	70	25.20	25.15	10.1	9.7	4	1.058	10.47	14:04	18:01	2.48	2.12
Southeast	SE-7	Upstairs	Backup	2/6/92	69	Not Analyzed	70	70	25.20	25.15	12.8	11.3	11.7	1.058	12.75	14:04	18:01	3.02	2.58
Southeast	SE-8	Basement	Primary	2/4/92	35	Analyzed	53	55	25.40	25.40	12	12.5	4	1.069	13.09	8:35	12:30	3.08	2.73
Southeast	SE-8	Basement	Backup	2/4/92	22	Not Analyzed	53	55	25.40	25.40	13	16	18.8	1.069	15.5	8:35	12:30	3.64	3.23
Southeast	SE-8	Basement	Blank	2/4/92	60	Analyzed	53		25.40										
Southeast	SE-8	Upstairs	Primary	2/4/92	61	Analyzed	70	70	25.40	25.40	20	19	5	1.069	20.84	9:00	11:27	3.06	2.64
Southeast	SE-8	Upstairs	Duplicate	2/4/92	67	Analyzed	70	70	25.40	25.40	12.5	11.5	8	1.069	12.83	9:00	11:27	1.89	1.62
Southeast	SE-8	Outdoor	Primary	2/4/92	96	Analyzed	53	35	25.40	25.40	12.6	14.5	13.1	1.058	14.34	13:57	17:45	3.27	2.96
Southeast	SE-8	Outdoor	Backup	2/4/92	92	Not Analyzed	53	35	25.40	25.40	10.6	12.5	15.2	1.058	12.22	13:57	17:45	2.79	2.52
Southeast	SE-9	Basement	Primary	2/11/92	079-N	Analyzed	64	63	26.10	26.10	12.8	13.2	3	1.069	13.9	8:37	13:03	3.70	3.31
Southeast	SE-9	Basement	Backup	2/11/92	37	Not Analyzed	64	63	26.10	26.10	13.5	14.3	5.6	1.069	14.86	8:37	13:03	3.95	3.54
Southeast	SE-9	Basement	Blank	2/11/92	53	Not Analyzed	64		26.10										
Southeast	SE-9	Upstairs	Primary	2/11/92	038-N	Analyzed	70	74	26.10	26.10	14	14	0	1.069	14.97	9:03	12:39	3.23	2.85
Southeast	SE-9	Upstairs	Backup	2/11/92	28	Not Analyzed	70	74	26.10	26.10	5.6	5.3	5.4	1.069	5.83	9:03	12:39	1.26	1.11
Southeast	SE-9	Outdoor		2/11/92	3	Invalid	28	31	26.10	26.16	13	23.5	44.7	1.069	19.51	9:21	12:53	4.14	3.96
Southeast	SE-9	Outdoor		2/11/92	24	Invalid	28	31	26.10	26.16	9.2	19	51.6	1.069	15.07	9:21	12:53	3.20	3.06
Unclassified	U-1	Basement		2/13/92	122	Invalid	67	68	25.95	26.00	12.7	12.7	0	1.0611	13.48	13:40	17:35	3.17	2.80
Unclassified	U-1	Basement		2/13/92	123	Invalid	67	68	25.95	26.00	10.2	10.5	2.9	1.0611	10.98	13:40	17:35	2.58	2.28
Unclassified	U-1	Basement	Blank	2/13/92	046-N	Invalid	67		25.95										
Unclassified	U-1	Upstairs		2/13/92	124	Broken													
Unclassified	U-1	Upstairs	Primary	2/13/92	126-N	Analyzed	78	74	26.10	26.00	12.4	12.3	0.8	1.0611	13.1	13:59	17:53	3.07	2.67



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APPROXIMATE SCALE IN FEET

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BURLINGTON NORTHERN	LIVINGSTON RAIL YARD REMEDIATION ADDENDUM 14-10	FEBRUARY 1991 GROUND WATER PLUME (PCE, DCE, TCE) vs INDOOR AIR SAMPLING RESULTS
ENVIROCON, INC.	AutoCADFILE: AQ-RSLT.DWG_L 3/27/92	FIGURE 1.0

homes specified in the IAQIWP. Three ambient air samples were collected and analyzed during the sampling event, with one ambient air sample being collected from each study area.

2.1.2 Sampling Activities During March 1992

The February investigative analytical results were evaluated by the MDHES; Camp, Dresser & McKee (CDM); and BNRR to determine whether additional samples should be collected. Sample collection at additional locations and vinyl chloride analyses were agreed upon during a March 2, 1992 conference call between the MDHES, CDM, ENSR, and Envirocon. A letter, detailing the followup investigation was submitted to the MDHES on March 5, 1992. The followup investigation was conducted from March 11 through March 13, 1992. The followup investigation included the following additional samples:

- Analysis of indoor air from the basement and upstairs for PCE, TCE, c-DCE, and t-DCE at the NE-1 residence;
- Analysis of indoor air for PCE, TCE, c-DCE and t-DCE at two additional residences in the northeast study area (NE-4 and NE-5);
- Analysis of indoor air for vinyl chloride at the NE-1, SE-2, and SE-8 residences and a randomly selected residence in the background study area (BG-2);
- Analysis of soil gas for PCE, TCE, c-DCE and t-DCE at the NE-3 and SE-2 residences and at a randomly selected residence in the background study area (BG-2); and
- Analysis of soil gas for vinyl chloride at the NE-1 and SE-5 residences.

Table 2 lists the indoor air and soil gas samples collected during the March followup investigation for PCE, TCE, c-DCE, and t-DCE analyses. Table 3 lists the basement air and soil gas samples collected during the March followup investigation for vinyl chloride analyses.

Table 2: Indoor Air Quality and Soil Gas Sampling Information for Samples Collected Between March 11 and March 13, 1992

Study Area	Resident	Location	Sample Type	Date	Sampler Number	Status	Initial Temp. (F)	Final Temp. (F)	Initial Pres. in. Hg	Final Pres. in. Hg	Initial Flow Rate ml/min	Final Flow Rate ml/min	Percent Diff	Corr. Factor	Corr. Flow Rate ml/min	Start Time	Final Time	Volume (liters)	Standard Volume (liters)
Background	BG-2	Soil Gas	Primary	3/12/92	106-V	Analyzed	62	62	25.65	25.65	28	28	0	0.975	27.30	15:39	16:32	1.45	1.28
Background	BG-2	Soil Gas	Backup	3/12/92	105-V	Not Analyzed	62	62	25.65	25.65	40	40	0	0.975	39.00	15:30	15:35	0.20	0.17
Background	BG-2	Soil Gas	Blank	3/12/92	070-V	Analyzed	62		25.65										
Background	BG-2A	Soil Gas	Primary	3/12/92	114-V	Analyzed	55	55	25.65	25.65	40	40	0	0.975	39.00	17:21	17:59	1.48	1.32
Northeast	NE-1	Basement	Primary	3/12/92	003-S	Analyzed	66	66	25.70	25.65	12.7	13.2	3.8	1.084	14.04	7:45	11:55	3.51	3.07
Northeast	NE-1	Basement	Backup	3/12/92	028-S	Not Analyzed	66	66	25.70	25.65	6	6	0	1.084	6.50	7:45	11:55	1.63	1.42
Northeast	NE-1	Basement	Blank	3/12/92	053-S	Analyzed	66		25.70										
Northeast	NE-1	Upstairs	Primary	3/12/92	125-S	Analyzed	72	73	25.70	25.65	12.2	12.3	0.8	1.084	13.28	8:08	12:13	3.25	2.82
Northeast	NE-1	Upstairs	Duplicate	3/12/92	065-S	Analyzed	72	73	25.70	25.65	12.8	13	1.5	1.084	13.98	8:08	12:13	3.43	2.96
Northeast	NE-3	Soil Gas	Primary	3/11/92	121-S	Analyzed	63	62	25.70	25.70	40	40	0	0.975	40	15:08	15:27	0.76	0.67
Northeast	NE-3	Soil Gas	Duplicate	3/11/92	017-S	Analyzed	63	62	25.70	25.70	40	40	0	0.975	40	15:03	15:05	0.10	0.09
Northeast	NE-4	Basement	Primary	3/11/92	025-S	Analyzed	61	63	25.65	25.65	12	11.5	4.3	1.084	12.74	13:56	17:37	2.81	2.48
Northeast	NE-4	Basement	Backup	3/11/92	024-S	Invalid	61	63	25.65	25.65	12.6	12.1	4.1	1.084	13.39	13:56	17:37	2.96	2.61
Northeast	NE-4	Basement	Blank	3/11/92	031-S	Analyzed	61		25.65										
Northeast	NE-4	Upstairs	Primary	3/11/92	020-S	Analyzed	73	72.5	25.65	25.65	14.1	14	0.7	1.084	15.23	13:11	17:11	3.66	3.16
Northeast	NE-4	Upstairs	Duplicate	3/11/92	009-S	Analyzed	73	72.5	25.65	25.65	11.3	11.3	0	1.084	12.25	13:11	17:11	2.94	2.54
Northeast	NE-5	Basement	Primary	3/13/92	061-S	Analyzed	54	57	25.70	25.70	23.5	23.7	0.8	0.975	23.01	10:52	12:50	2.72	2.43
Northeast	NE-5	Basement	Backup	3/13/92	019-S	Not Analyzed	54	57	25.70	25.70	27	27.2	0.7	0.975	26.42	10:52	12:50	3.12	2.79
Northeast	NE-5	Basement	Blank	3/13/92	118-S	Not Analyzed	54		25.70										
Northeast	NE-5	Upstairs	Primary	3/13/92	050-S	Analyzed	63	63	25.74	25.70	13.1	16.4	9.7	0.975	14.38	8:35	12:37	3.48	3.07
Northeast	NE-5	Upstairs	Backup	3/13/92	090-S	Not Analyzed	63	63	25.74	25.70	13.7	17.7	11.7	0.975	15.31	8:35	12:37	3.70	3.27
Southeast	SE-2	Soil Gas	Primary	3/12/92	080-S	Analyzed	55	55	25.72	25.72	40	40	0	0.975	39.00	9:42	10:01	0.74	0.66
Southeast	SE-2	Soil Gas	Duplicate	3/12/92	069-S	Analyzed	55	55	25.72	25.72	39.5	39.5	0	0.975	38.51	9:36	9:38	0.10	0.09
Southeast	SE-2	Soil Gas	Blank	3/12/92	026-S	Analyzed	55		25.72										
Unclassified	U-1	Basement	Primary	3/13/92	37-S	Analyzed	71	70	25.72	25.70	25.4	27.5	7.6	1.084	28.67	9:25	11:37	3.78	3.29
Unclassified	U-1	Basement	Backup	3/13/92	56-S	Not Analyzed	71	70	25.72	25.70	16.8	17.6	4.5	1.084	18.64	9:25	11:37	2.46	2.14
Unclassified	U-1	Basement	Blank	3/13/92	73-S	Not Analyzed													

Table 3: Indoor Air Quality and Soil Gas Sampling Information for Samples Collected Between March 11 and March 13, 1992 for Vinyl Chloride.

Study Area	Resident	Location	Sample Type	Date	Sampler Number	Status	Initial Temp. (F)	Final Temp. (F)	Initial Pres. in. Hg	Final Pres. in. Hg	Initial Flow Rate ml/min	Final Flow Rate ml/min	Percent Diff.	Corr. Factor	Corr. Flow Rate ml/min	Start Time	Final Time	Volume (liters)	Standard Volume (liters)
Background	BG-2	Basement	Primary	3/12/92	107-V	Analyzed	62	61	25.65	25.65	39.7	37.5	5.9	1.084	41.84	13:18	17:24	10.29	9.09
Background	BG-2	Basement	Backup	3/12/92	108-V	Not Analyzed	62	61	25.65	25.65	33	30.5	8.2	1.084	34.42	13:18	17:24	8.47	7.47
Background	BG-2	Basement	Blank	3/12/92	111-V	Analyzed	62		25.65										
Northeast	NE-1	Basement	Primary	3/12/92	109-V	Analyzed	66	66	25.70	25.65	40	38.6	3.6	0.975	38.32	7:56	12:04	9.50	8.33
Northeast	NE-1	Basement	Duplicate	3/12/92	004-V	Analyzed	66	66	25.70	25.65	29	27.7	4.7	0.975	27.64	7:56	12:04	6.86	6.01
Northeast	NE-1	Basement	Blank	3/12/92	007-V	Analyzed	66		25.70										
Northeast	NE-1	Soil Gas	Primary	3/12/92	045-V	Analyzed	54	54	25.70	25.70	40	40	0	0.975	39.00	11:13	11:51	1.48	1.33
Northeast	NE-1	Soil Gas	Backup	3/12/92	033-V	Not Analyzed	54	54	25.70	25.70	40	40	0	0.975	39.00	11:06	11:11	0.20	0.18
Southeast	SE-2	Basement	Primary	3/12/92	077-V	Analyzed	72	75	25.65	25.65	40	36	11.1	0.975	37.05	13:27	17:41	9.41	8.12
Southeast	SE-2	Basement	Duplicate	3/12/92	055-V	Analyzed	72	75	25.65	25.65	19.3	20	3.5	0.975	19.16	13:27	17:41	4.87	4.20
Southeast	SE-2	Basement	Blank	3/12/92	076-V	Analyzed	72		25.65										
Southeast	SE-5	Soil Gas	Primary	3/12/92	048-V	Analyzed	54	57	25.65	25.70	40	40	0	0.975	39.00	9:20	9:58	1.48	1.32
Southeast	SE-5	Soil Gas	Backup	3/12/92	044-V	Not Analyzed	54	57	25.65	25.70	40	40	0	0.975	39.00	9:12	9:17	0.20	0.17
Southeast	SE-8	Basement	Primary	3/13/92	112-V	Analyzed	54	60	25.74	25.70	40.5	35.5	14.1	1.084	41.19	8:18	12:21	10.01	8.94
Southeast	SE-8	Basement	Backup	3/13/92	008-V	Not Analyzed	54	60	25.74	25.70	34.5	30.5	13.1	1.084	35.23	8:18	12:21	8.56	7.64
Southeast	SE-8	Basement	Blank	3/13/92	115-V	Analyzed	54		25.74										

Since a valid air sample was not previously collected for the living area of the NE-1 residence, upstairs and basement samples for PCE, TCE, c-DCE, and t-DCE were collected. The additional sample collected in the basement also provided information on the temporal variation of the chlorinated ethenes. Basement samples were collected on February 5 and February 14 at the NE-1 residence (Table 1). A basement sample for vinyl chloride was also collected at the NE-1 residence.

Indoor air samples were collected at two additional residences (NE-4 and NE-5) within the northeast study area and analyzed for PCE, TCE, c-DCE, and t-DCE. Since the three sampled homes in the northeast study area have chlorinated ethene concentrations higher than the background study area, additional characterization was warranted.

Vinyl chloride analyses were conducted for the basement samples of the NE-1, SE-2, and SE-8 residences. In addition to anthropogenic sources for vinyl chloride, it may also be formed by the dechlorination of c-DCE or t-DCE. Although dechlorination of chlorinated ethenes is more readily accomplished in an anaerobic environment, the PCE, TCE, and DCE-isomer analytical results for the February sampling round at the NE-1, SE-2, and SE-8 residences indicated the potential for vinyl chloride formation. One residence (BG-2) was randomly selected from the existing background study area to provide a measure of the background concentration for vinyl chloride.

Soil gas samples were collected at the NE-3 and SE-2 residences and at two locations at a randomly selected background study area residence (BG-2) and analyzed for PCE, TCE, c-DCE, and t-DCE. The NE-3 residence lies outside the inferred ground-water chlorinated ethene plume and the SE-2 residence lies within an anomalous section of the plume as shown on Figure 1.0. Soil gas samples were collected at the NE-1 and SE-5 residences and analyzed for vinyl chloride. These samples were included in the followup investigation at the request of CDM.

2.2 Building-Structure and House-Activity Information

Building-Structure Surveys and House-Activity Forms were completed for all homes by the field sampling teams with the assistance of each resident. Copies of the completed Building-Structure Surveys and House-Activity Forms are included in Appendix A. The Building-Structure Surveys include information on the type and size each resident's basement and/or crawlspace, the type of heating system, and the chemicals stored in each home. The House-Activity Forms include information on the possible release of organic chemicals into the home that may have increased the concentrations of PCE, TCE, c-DCE, t-DCE, or vinyl chloride. Potential releases of organic chemicals by residents are discussed in the next section.

3.0 ANALYTICAL RESULTS

3.1 Analytical Methodology

All laboratory analyses for this study were conducted by Berkeley Analytical Associates of Richmond, California. All samples were collected with multisorbent samplers that consisted of Tenex-TA, Carboxen molecular sieve and activated carbon, in series. All analyses were analyzed by thermal desorption, gas chromatography, mass spectrometry. The mass spectrometer was operated in selected ion monitoring (SIM) mode to enhance the selectivity and sensitivity of the analysis.

Table 4 contains the risk-based (10^{-6} cancer risk) target detection limits for indoor air recommended for the chlorinated ethenes by CDM in their "Comments on Revised Indoor Air Quality Investigation Work Plan," dated January 23, 1992. Table 4 also contains the sample quantitation limit ranges for indoor and ambient air samples reported by Berkeley Analytical Associates. The sample quantitation limits vary slightly due to small differences in the sample volumes for each sample. In all cases, the sample quantitation limits are less than the target detection limits recommended by CDM.

Table 4: Target Detection Limits and Sample Quantitation Limits for Chlorinated Ethene Compounds.

Chemical Compound	Target Detection Limit (ug/m^3)	Sample Quantitation Limit Range (ug/m^3)
Tetrachloroethene	4.5	0.15 - 0.31
Trichloroethene	0.5	0.15 - 0.31
cis-1,2-Dichloroethene	35	0.15 - 0.31
trans-1,2-Dichloroethene	35	0.15 - 0.31
Vinyl Chloride	0.05	0.02 - 0.03

3.2 Data Validation

The analytical results were validated by evaluating the following:

- Holding times;
- Comparison with field and system blanks;
- Comparison with field duplicate results; and
- Field measurements and field log entries.

The results of the data validation, which includes tables of the relative percent differences between the field samples and the duplicate samples, are presented in Appendix B. Berkeley Analytical Associates' Quality Assurance Program for the analysis of volatile organic compounds is also included in Appendix B.

3.3 Analytical Results

The analytical results for the 3 ambient air samples, the 20 residential locations, and the 6 soil gas samples are located in Appendix B. Table 5 summarizes the PCE, TCE, c-DCE, and t-DCE analytical results for the February sampling event. Table 6 summarizes the PCE, TCE, c-DCE, and t-DCE analytical results for the March sampling event. Table 7 summarizes the vinyl chloride analytical results for the March sampling event.

3.3.1 Ambient Air Results

The three ambient air samples were collected on different days. Hourly averages of wind speed and wind direction information were collected at the LRY downwind ambient air station. An ambient air sample was collected from 13:57 to 17:45 on February 4, 1992 in the southeast study area as shown on Figure 1.0. The wind speed varied from 9 to 12 mph, and the azimuth of the wind direction varied from 220° to 233° (due North equals 0°). An ambient air sample was collected from

Table 5: Analytical Results for Indoor and Outdoor Air Samples Collected During February 1992.

Study Area	Resident	Location	Sampler Number	Sample Type	Standard Volume	PCE (ug/m3)	TCE (ug/m3)	cis-1,2-DCE (ug/m3)	trans-1,2-DCE (ug/m3)
Background	BG-1	Basement	90	Primary	2.69	1.12	< 0.19	< 0.19	< 0.19
Background	BG-1	Upstairs	64	Primary	2.61	1.19	< 0.19	< 0.19	< 0.19
Background	BG-2	Basement	29	Primary	3.09	1.36	0.36	< 0.16	< 0.16
Background	BG-2	Upstairs	82	Primary	2.64	1.44	1.06	< 0.19	< 0.19
Background	BG-3	Basement	10	Primary	2.85	1.33	< 0.18	< 0.18	< 0.18
Background	BG-3	Upstairs	119	Primary	2.66	1.47	0.19	< 0.19	< 0.19
Background	BG-3	Outdoor	120	Primary	2.72	1.47	< 0.18	< 0.18	< 0.18
Background	BG-4	Basement	041-N	Primary	3.15	1.94	0.25	< 0.16	< 0.16
Background	BG-4	Upstairs	127-N	Primary	2.64	2.54	0.3	< 0.19	< 0.19
Background	BG-5	Basement	50	Primary	2.96	0.61	2.71	< 0.17	< 0.17
Background	BG-5	Upstairs	32	Primary	2.87	0.56	1.11	< 0.17	< 0.17
Northeast	NE-1	Basement	85	First Time	2.91	64.3	1.07	0.24	< 0.17
Northeast	NE-1	Basement	043-N	Primary	3.02	70.2	1.42	0.4	< 0.17
Northeast	NE-1	Outdoor	021-N	Primary	2.23	1.52	< 0.22	< 0.22	< 0.22
Northeast	NE-2	Basement	5	Primary	2.69	18.9	0.45	< 0.19	< 0.19
Northeast	NE-2	Basement	89	Duplicate	2.62	17.2	0.31	< 0.19	< 0.19
Northeast	NE-2	Upstairs	43	Primary	2.48	5.73	0.24	< 0.20	< 0.20
Northeast	NE-3	Basement	51	Primary	2.63	8.56	1.98	< 0.19	< 0.19
Northeast	NE-3	Upstairs	83	Primary	2.67	13.7	3.33	< 0.19	< 0.19
Southeast	SE-1	Basement	104	Primary	2.69	3.35	< 0.19	< 0.19	< 0.19
Southeast	SE-1	Upstairs	93	Primary	2.48	27	0.77	< 0.20	< 0.20
Southeast	SE-1	Upstairs	102	Duplicate	1.90	24.6	0.68	< 0.26	< 0.26
Southeast	SE-2	Basement	058-N	Primary	2.68	6.31	0.3	0.26	< 0.19
Southeast	SE-2	Basement	014-N	Duplicate	2.62	6.87	0.31	0.27	< 0.19
Southeast	SE-2	Upstairs	082-N	Primary	2.67	5.47	0.3	0.26	< 0.19
Southeast	SE-3	Basement	66	Primary	2.73	1.39	0.22	< 0.18	< 0.18
Southeast	SE-3	Upstairs	52	Primary	2.73	1.43	< 0.18	< 0.18	< 0.18
Southeast	SE-4	Basement	015-N	Primary	2.92	2.19	< 0.17	< 0.17	< 0.17
Southeast	SE-4	Upstairs	58	First Time	2.71	3.84	1.62	< 0.18	< 0.18
Southeast	SE-4	Upstairs	094-N	Primary	2.81	5.2	1.71	< 0.18	< 0.18
Southeast	SE-5	Basement	001-N	Primary	3.15	43.2	2.35	< 0.16	< 0.16
Southeast	SE-5	Basement	030-N	Duplicate	2.14	51.4	1.45	< 0.23	< 0.23
Southeast	SE-5	Upstairs	117-N	Primary	2.22	11.3	0.9	< 0.23	< 0.23
Southeast	SE-6	Basement	47	Primary	2.73	1.4	0.22	< 0.18	< 0.18
Southeast	SE-6	Upstairs	26	Primary	2.77	1.63	0.22	< 0.18	< 0.18
Southeast	SE-7	Basement	19	Primary	2.80	1.11	0.21	< 0.18	< 0.18
Southeast	SE-7	Upstairs	14	Primary	2.12	1.23	< 0.24	< 0.24	< 0.24
Southeast	SE-8	Basement	35	Primary	2.73	< 1.83	0.29	0.22	0.22
Southeast	SE-8	Upstairs	61	Primary	2.64	1.02	0.49	0.23	< 0.19
Southeast	SE-8	Upstairs	67	Duplicate	1.62	0.93	0.49	< 0.31	< 0.31
Southeast	SE-8	Outdoor	96	Primary	2.96	1.55	< 0.17	< 0.17	< 0.17
Southeast	SE-9	Basement	079-N	Primary	3.31	1.93	0.15	< 0.15	< 0.15
Southeast	SE-9	Upstairs	038-N	Primary	2.85	1.4	< 0.18	< 0.18	< 0.18
Unclassified	U-1	Upstairs	126-N	Primary	2.67	2.85	0.3	< 0.19	< 0.19

Table 6: **Analytical Results for Indoor Air and Soil Gas Samples Collected During March 1992.**

Study Area	Resident	Location	Sampler Number	Sample Type	Standard Volume	PCE (ug/m3)	TCE (ug/m3)	cis-1,2-DCE (ug/m3)	trans-1,2-DCE (ug/m3)
Background	BG-2	Soil Gas	106-V	Primary	1.28	14.4	5	<0.39	<0.39
Background	BG-2A	Soil Gas	114-V	Primary	1.32	12.8	9.24	<0.38	<0.38
Northeast	NE-1	Basement	003-S	Primary	3.07	82.1	1.5	0.26	<0.16
Northeast	NE-1	Upstairs	125-S	Primary	2.82	27.9	0.6	<0.18	<0.18
Northeast	NE-1	Upstairs	065-S	Duplicate	2.96	26.5	0.61	<0.17	<0.17
Northeast	NE-3	Soil Gas	121-S	Primary	0.67	1.34	<0.75	<0.75	<0.75
Northeast	NE-3	Soil Gas	017-S	Duplicate	0.09	<5.56	<5.56	<5.56	<5.56
Northeast	NE-4	Basement	025-S	Primary	2.48	18.4	0.48	NI	NI
Northeast	NE-4	Upstairs	020-S	Primary	3.16	5.66	0.57	<0.16	<0.16
Northeast	NE-4	Upstairs	009-S	Duplicate	2.54	6.18	1.3	0.63	0.39
Northeast	NE-5	Basement	061-S	Primary	2.43	0.58	<0.21	<0.21	<0.21
Northeast	NE-5	Upstairs	050-S	Primary	3.07	1.07	0.23	<0.16	<0.16
Southeast	SE-2	Soil Gas	080-S	Primary	0.66	9.09	9.55	<0.76	<0.76
Southeast	SE-2	Soil Gas	069-S	Duplicate	0.09	5.56	<5.56	<5.56	<5.56
Unclassified	U-1	Basement	037-S	Primary	3.29	1.16	<0.15	<0.15	<0.15

NI No information due to water interference in sampler tube.

Table 7: Vinyl Chloride Analytical Results for Indoor Air and Soil Gas Samples Collected During March 1992.

Study Area	Resident	Location	Sampler Number	Sample Type	Standard Volume	Vinyl Chloride (ug/m3)
Background	BG-2	Basement	107-V	Primary	9.09	<0.02
Northeast	NE-1	Basement	109-V	Primary	8.33	<0.02
Northeast	NE-1	Basement	004-V	Duplicate	6.01	<0.03
Northeast	NE-1	Soil Gas	045-V	Primary	1.33	<0.15
Southeast	SE-2	Basement	077-V	Primary	8.12	0.8
Southeast	SE-2	Basement	055-V	Duplicate	4.20	0.64
Southeast	SE-5	Soil Gas	048-V	Primary	1.32	<0.15
Southeast	SE-8	Basement	112-V	Primary	8.94	<0.02

9:12 to 12:55 on February 12, 1992 in the background study area, as shown on Figure 1.0. The wind speed varied from 10 to 15 mph, and the azimuth of the wind direction varied from 206° to 242°. An ambient air sample was collected from 8:38 to 12:34 on February 14, 1992 in the northeast study area, as shown on Figure 1.0. The wind speed varied from 8 to 11 mph, and the azimuth of the wind direction varied from 203° to 236°.

3.3.2 Indoor Air Results

A comparison of all the PCE analytical results demonstrates the ubiquitous nature of PCE in the Livingston area. All outdoor ambient air samples and all indoor air samples contained detectable amounts of PCE. The SE-8 basement sample was reported as non-detected at 1.83, because PCE was found in the associated field blank at a concentration greater than 20% of the sample value. TCE was not found in the ambient air samples, but was found at low levels in several background study area residences. The DCE isomers were infrequently detected, with c-DCE detected at four residences and t-DCE detected at two residences. The NE-4 upstairs primary sample did not contain either c-DCE or t-DCE, but both compounds were detected in the duplicate sample. Vinyl chloride was detected at only one residence (SE-2) and was confirmed by a field duplicate sample.

Several homes show higher PCE and TCE concentrations in the upstairs sample than in the basement sample. The residences that show the most significant differences for PCE are the SE-4 residence (5.2 ug/m^3 upstairs vs. 2.19 ug/m^3 basement); the NE-3 residence (13.7 ug/m^3 upstairs vs. 8.56 ug/m^3 basement); and the SE-1 residence (27.0 ug/m^3 upstairs vs. 3.35 ug/m^3 basement). The same pattern of significant differences is repeated for TCE in the SE-4 residence (1.71 ug/m^3 upstairs vs. < 0.17 ug/m^3 basement); the NE-3 residence (3.33 ug/m^3 upstairs vs. 1.98 ug/m^3 basement); and the SE-1 residence (0.77 ug/m^3 upstairs vs. < 0.19 ug/m^3 basement). This indicates that PCE and TCE air sources are from household chemical use in the

living area rather than emanating from the ground water. The field logbook entry for the SE-1 residence notes that a new carpet was installed two weeks prior to sampling the residence. The highest TCE value measured during this investigation was the upstairs sample at the NE-3 residence.

Table 7 summarizes the analytical results for vinyl chloride. The SE-2 residence is the only residence out of the 4 sampled that contained a detectable concentration of vinyl chloride (0.8 ug/m^3). This residence overlies the anomalous part of the ground-water plume and is across the street from a petroleum storage facility. The vinyl chloride concentration is believed to be anomalous because neither c-DCE or t-DCE were found in the soil gas sample collected near the residence. In addition, the c-DCE concentration in the basement of the SE-2 residence is less than one-third of the vinyl chloride value. If the vinyl chloride came from the dehalogenation of c-DCE, one would expect the vinyl chloride value to be less than the c-DCE value.

3.2.3 Soil Gas Results

Four soil gas samples were collected at three residences (NE-3, BG-2, and SE-2) and analyzed for PCE, TCE, c-DCE, and t-DCE. All four of the soil gas samples contained detectable concentrations of PCE. The soil gas PCE concentrations varied from a high of 14.4 ug/m^3 at background study area residence BG-2, to a low of 1.34 ug/m^3 at northeast study area residence NE-3. Three out of the four soil gas samples contained detectable concentrations of TCE. The soil gas TCE concentrations varied from a high of 9.55 ug/m^3 at the southeast study area residence SE-2, to a low of 5.0 ug/m^3 at background study area residence BG-2. None of the soil gas samples contained detectable concentrations of either c-DCE or t-DCE. The background study area soil gas samples indicate that a non-LRY chlorinated ethene source is present at the BG-2 residence.

The above soil gas analytical results show poor correlation to the concentrations measured in the basements of the three residences. Residence NE-3 contains the highest PCE concentration in the basement (8.56 ug/m^3), but the lowest soil gas PCE concentration (1.34 ug/m^3). Residence NE-3 also contained the highest TCE concentration in the basement (1.98 ug/m^3), but TCE was not detected in the soil gas sample. Residence BG-2 contained the lowest PCE concentration in the basement (1.36 ug/m^3), but the highest soil gas PCE concentration (14.4 ug/m^3). The mass ratio of TCE to PCE is 1.05 for the soil gas sample at the SE-2 residence, but is 0.048 for the basement sample. Based on these observations, it is apparent that soil gas samples that contain detectable concentrations of VOCs are not useful indicators of indoor chlorinated ethene concentrations.

Two soil gas samples were collected (NE-1 residence and the SE-5 residence) for vinyl chloride analysis. Neither soil gas sample contained a detectable concentration of vinyl chloride.

3.3.4 Statistical Evaluation

Tables 8A and 8B present summary statistics for PCE and TCE, respectively. The statistics for the background study area show a small variance for PCE compared to the northeast and southeast study areas. PCE concentrations for the outdoor ambient air samples show no real variance, which indicates a steady, constant source of PCE in the city of Livingston unrelated to the LRY. The ambient air arithmetic mean and the background study area arithmetic mean for PCE are almost identical and indicate that the ambient air PCE source is the main component to the background study area indoor air PCE concentrations.

Comparison of the ambient air and background study area arithmetic means with the concentrations in the southeast study area shows that the majority of the southeast study area residences contain only background concentrations of PCE.

Table 8A: Summary Statistics of Tetrachloroethene for Six Different Area Classifications.

Statistical Variable	All Basement Samples	All Upstairs Samples	Ambient Air Samples	Background Samples	Southeast Samples	Northeast Samples
Sample Size	20	20	3	11	18	10
Arithmetic Mean	9.94	6.02	1.51	1.37	6.58	18.3
Geometric Mean	3.08	3.06	1.51	1.26	3.06	8.54
Median	1.88	2.08	1.52	1.36	1.88	11.1
Mode	1.4	1.47	1.47	1.47	1.4	6.18
Variance	393.6	66.2	0.0016	0.305	122.3	577.2
Minimum	0.58	0.56	1.47	0.56	1.02	0.58
Maximum	82.1	27.9	1.55	2.54	43.2	82.1
Lower Quartile	1.25	1.32	1.47	1.12	1.4	5.73
Upper Quartile	7.44	5.96	1.55	1.47	5.47	18.9

Table 8B: Summary Statistics of Trichloroethene for Six Different Area Classifications.

Statistical Variable	All Basement Samples	All Upstairs Samples	Ambient Air Samples	Background Samples	Southeast Samples	Northeast Samples
Sample Size	20	20	3	11	18	10
Arithmetic Mean	0.6	0.63	0.09	0.58	0.48	1.02
Geometric Mean	0.3	0.35	0.09	0.29	0.28	0.63
Median	0.24	0.3	0.09	0.25	0.22	0.54
Mode	0.09	0.09	0.08	0.09	0.22	0.45
Variance	0.676	0.62	0.00023	0.64	0.382	1.048
Minimum	0.075	0.09	0.08	0.09	0.08	0.105
Maximum	2.71	3.33	0.11	2.71	2.35	3.33
Lower Quartile	0.12	0.16	0.08	0.09	0.12	0.24
Upper Quartile	0.46	0.92	0.11	1.06	0.49	1.5

Note: Values below the detection limit are multiplied by 0.5 prior to calculation of the summary statistics.

This is supported by the fact that the median value for PCE in the southeast study area is equal to the background and ambient air arithmetic means (Table 8A). Slightly elevated PCE concentrations are found at the SE-2 residence. PCE concentrations at the SE-1 and SE-4 residences have already been described as anomalous because the upstairs concentrations are higher than the basement concentrations. The SE-5 residence contains the highest concentration of PCE in the southeast study area, at 50.2 ug/m^3. The field logbook entry for the SE-5 residence, however, noted a strong varnish smell and the House-Activity Form states that a portion of the interior was varnished on February 6.

The summary statistics in Table 8A, when compared to Tables 5 and 6 indicate that the northeast study area residences have PCE concentrations that are elevated above background PCE concentrations. The NE-1 residence contains both the highest basement PCE concentration, at 82.1 ug/m^3, and the highest upstairs PCE concentration at 27.9 ug/m^3.

In addition to the comparison of PCE concentrations to site-specific statistical values in Table 8, Table 9 provides information on the distribution of PCE in outdoor and indoor air across the United States. The PCE data is from a national VOCs data base that was developed by the U.S. Environmental Protection Agency in 1983 and revised in 1988. The outdoor air summary statistics presented in Table 9 are derived from 3226 values and include remote, rural, suburban, urban, and source-dominated site types. The indoor air summary statistics presented in Table 9 are derived from 2195 values. The concentrations for PCE measured in Livingston should not be directly compared to the national data, since the national data is a synthesis of widely divergent site types. However, it is important to note that the indoor air summary statistics are higher that the outdoor air statistics. This is indicative of the use of PCE in the dry-cleaning industry and the wide-spread use of household chemicals that contain PCE.

Table 9: Daily Outdoor and Indoor Air Concentrations for Tetrachloroethene (ug/m^3).

Location	Arithmetic Mean	Median	Lower Quartile	Upper Quartile
Outdoor	5.8	2.4	0.81	5.9
Indoor	20.7	5.0	1.7	11.0

Source: Shah, Jitendra J., and Hanwant B. Singh, "Distribution of volatile organic chemicals in outdoor and indoor air, A national VOCs data base," Environ. Sci. Technol., Vol. 22, No. 12, 1988.

4.0 PRELIMINARY RISK ASSESSMENT PERFORMED BY ENSR CONSULTING AND ENGINEERING

The purpose of this preliminary risk assessment is to evaluate the potential human health risks from the inhalation of indoor air chemical concentrations in the residences located near the LRY. This preliminary assessment serves as a decision-making tool for determining whether or not the chemical concentration levels warrant a further evaluation in the near future or if these areas can be addressed at a future date as the remediation progresses. This preliminary risk assessment follows the EPA's "Risk Assessment Guidance For Superfund: Human Health Evaluation Manual" (RAGS). A four-step process for baseline risk assessment was used as outlined in RAGS; however, each step conducted here is abbreviated and is not as extensive as a typical baseline risk assessment. The formal risk assessment will be conducted by the MDHES. These steps include: data collection and evaluation; toxicity assessment; exposure assessment; and risk characterization.

4.1 Data Collection and Evaluation

In this step relevant site data is generally gathered and evaluated for their adequacy in describing the site and usefulness in performing the site risk assessment. In choosing the chemicals of potential concern, chemical elimination is usually performed based on abundance and their potential to cause adverse health effects. However, for the "worst-case" risk analysis all the chemicals found in indoor air samples, which include PCE, TCE, c-DCE, t-DCE, and vinyl chloride, are evaluated in this preliminary risk assessment. The concentration levels evaluated for each chemical were the highest overall concentrations measured during the study. The highest detected concentrations of PCE, TCE, c-DCE, t-DCE, and vinyl chloride were 82.1 ug/m^3, 3.33 ug/m^3, 0.63 ug/m^3, 0.39 ug/m^3, and 0.8 ug/m^3, respectively.

The indoor air sample collection and analyses did not distinguish between the potential source contributions of the chemical concentrations from the site versus other sources. For example, some of the basements contained items such paints, solvents, and glues that may contribute to the overall chlorinated ethene compound levels detected in the air. As discussed previously, the detected vinyl chloride value is believed to be an anomaly; however, it is included in the risk assessment of the highest overall concentrations. This risk assessment is, therefore, designed to provide a conservative initial risk calculation based on total measured concentrations of PCE, TCE, c-DCE, and t-DCE. Appendix C contains a toxicological profile for each chemical which also describes the variety of uses and formulations of these chemicals.

4.2 Toxicity Assessment

This step describes the toxicological effects of each chemical selected for evaluation. Each chemical was researched to provide a hazard identification and regulatory dose-response determination. Toxic effects for noncarcinogenic compounds are based on the reference dose (RfD). The RfD is the value assigned to a compound whereby a daily exposure of the compound at or below the reference dose will not cause any appreciable health effects.

The EPA uses a "weight-of-evidence" classification for carcinogenicity. The classification system is listed below.

- Group A: Human carcinogen
- Group B: Probable Human Carcinogen
- Group C: Possible Human Carcinogen
- Group D: Not classifiable as to human carcinogenicity
- Group E: Evidence of noncarcinogenicity for humans

At low doses, the probability of contracting cancer in a lifetime is assumed to be proportional to the cumulative lifetime dose. The coefficient relating dose to risk

is called the cancer slope factor (CSF).

CSFs and RfDs for this risk assessment were obtained from the EPA Integrated Risk Information System (IRIS), if available, or from the Health Effects Assessment Summary Tables (HEAST), when information was not available in IRIS. Where appropriate for the risk calculations, a subchronic value was obtained for the subchronic calculations.

The toxicity assessment provides information that is used in conjunction with the exposure assessment to estimate potential risks posed to human receptors. The following is a brief summary of the carcinogenic classification and provides the quantitative indices of toxicity for each chemical evaluated in this risk assessment. A more extensive toxicological profile for each chemical is provided in Appendix C.

4.2.1 Tetrachloroethene

EPA has classified PCE as a B2 - Probable Human Carcinogen based on inadequate evidence in humans and sufficient evidence of carcinogenicity from animal studies. EPA has derived an oral and inhalation CSF for PCE of 0.051 $(\mathrm{mg/kg/day})^{-1}$ and 0.00182 $(\mathrm{mg/kg/day})^{-1}$ for oral and inhalation routes, respectively. An oral RfD of 0.01 mg/kg/day has been established for PCE. The uncertainty factor associated with this value is 1000. A subchronic oral RfD of 0.1 mg/kg/day has also been established. The subchronic oral RfD is associated with an uncertainty factor of 100. No RfD has been established for the inhalation route of exposure. For purposes of this evaluation, chronic and subchronic values for the oral route of exposure were used in place of an inhalation RfD.

4.2.2 Trichloroethene

The EPA has classified TCE as a B2 - Probable Human Carcinogen based on

inadequate evidence in humans and sufficient evidence of carcinogenicity from animal studies. The EPA derived an oral administered CSF for TCE of 0.011 $(mg/kg/day)^{-1}$ and an inhalation adsorbed CSF of 0.017 $(mg/kg/day)^{-1}$.

4.2.3 1,2-Dichloroethene Isomers

Trans-1,2-dichloroethene has not been evaluated as a possible substance/agent for evidence of human carcinogenic potential. EPA has derived a chronic and subchronic oral RfD for t-DCE of 0.02 mg/kg/day and 0.2 mg/kg/day, respectively. The uncertainty factors associated with these values are 1000 and 100, respectively. Neither an inhalation RfD nor CSF has been determined. In this risk assessment, where there is no value for the inhalation route of exposure, values developed for the oral route of exposure were used.

Cis-1,2-dichloroethene has been classified as D - Not Classifiable as to Human Carcinogenicity. EPA has derived a chronic and subchronic oral RfD for c-DCE of 0.01 mg/kg/day and 0.1 mg/kg/day, respectively. The uncertainty factors associated with these values are 3000 and 300, respectively. Neither an inhalation RfD nor CSF has been determined. As for t-DCE, where there is no value for the inhalation route of exposure, values developed for the oral route of exposure were used.

4.2.4 Vinyl Chloride

EPA has classified vinyl chloride as a Class A - Human Carcinogen based on adequate evidence of carcinogenicity from epidemiologic studies. The CSF for vinyl chloride by the oral route is 1.9 $(mg/kg/day)^{-1}$ and the CSF is 0.294 $(mg/kg/day)^{-1}$ as calculated from the unit cancer risk factor. RfDs are not established for vinyl chloride.

4.2.5 Absorption Adjustment Factors

Absorption adjustment factors (AAF) for the inhalation pathway are included in the exposure assessment calculations for each chemical. The following discussion describes the rationale for the absorption adjustment factors used in this evaluation. The inhalation cancer unit risk factor for PCE is based upon an inhalation study in mice. It is assumed that inhalation is similar in humans and mice so the AAF (inhalation-vapor) is 1.0. The inhalation CSF for TCE is based on metabolized dose from an inhalation study in mice. ENSR assumes that the absorption and metabolism of TCE from respirable particles retained in the lung or vapor is the same as the human absorption and metabolism assumed by the EPA in deriving the CSF. As discussed above, the exposure dose estimated by the risk assessment must be converted into a metabolized dose. Thus, the AAF (inhalation-vapor and -particulate) is (100%) x (35%) = 0.35. ENSR assumes that absorption for both forms of 1,2-dichloroethene from respirable soil particles retained in the lung is 100%. Thus, the AAF (inhalation) for noncarcinogenic effects is 100%/100% = 1.0. The inhalation unit risk value for vinyl chloride is based on a 1-year inhalation study in rats. ENSR assumes that the absorption and metabolism of vinyl chloride from respirable particles retained in the lung or vapor is 100%. Thus, the AAF (inhalation) for carcinogenic effects is 100%/100% = 1.0.

4.3 Exposure Assessment

An exposure pathway analysis investigates the relationship between the contaminant release source and the exposed human population. A completed exposure pathway consists of four basic components which include:

- A contaminant source and release mechanism;
- A contaminant retention or receiving transport medium;
- A point of potential human contact with contaminated media; and
- An exposure route (e.g. inhalation) at the contact point.

Because this is a preliminary risk assessment that is to be used as a tool to determine whether further evaluation is warranted, this exposure assessment evaluates only the indoor air residential inhalation exposure pathway. This exposure assessment evaluates the potential release of vapors from the LRY that may have penetrated into the nearby residences and impacted the indoor air quality. This evaluation considers the most conservative site-specific exposure parameters.

The indoor air study focused on collecting samples from residences with basements. Generally, the highest concentrations of the chlorinated ethene compounds were found in the basements of the residences rather than the upstairs portion of the homes. However, as one can see from Tables 5 and 6, there are a few anomalies where chemical concentrations are higher is the upstairs portion of the residences.

According to the Building-Structure Survey, the residents of the NE-3 home spend the most time in the basement. The residence is a split-level home and the basement is part of the living area of the home. The second longest period of time spent per week in the basement recorded was 70 to 80 hours per week, occurring twice on the residential survey.

Six hours per day is the upper 95TH percent confidence value of the arithmetic mean for time spent in the basement for all homes in the study and is based on the Basement-Structure Survey forms. If the background study area is eliminated from the data set, the upper 95TH percent confidence value of the arithmetic mean for time spent in the basement is less than 8 hours per week. The residential chronic exposure is evaluated based on an 8 hour per day exposure time. A more conservative exposure assessment was performed based on 1.5 times the site-specific exposure time (12 hours per day) to provide an estimate for potential future changes in residential use. A subchronic exposure scenario was also evaluated for the highest overall concentrations detected in the indoor air, assuming an individual is exposed

for 24 hours per day for 1 year. For comparison purposes, the same parameters will be used to evaluate concentration levels equivalent to the upper 95^{TH} percent confidence value of the arithmetic mean for the combined northeast and southeast study areas. The 95^{TH} percent comparisons did not include vinyl chloride because it was detected only once. These concentrations are 34.08 ug/m^3 for PCE, 1.04 ug/m^3 for TCE, 0.25 ug/m^3 for c-DCE, and 0.19 ug/m^3 for t-DCE. Exposure assessment calculations are provided in Appendices D and E.

A site-specific risk analysis is performed for the NE-1 residence in the northeast study area. Samples were collected upstairs and in the basement on March 12, 1992. The exposure scenario for the evaluation of the chemicals in the basement used the site-specific time spent in the basement listed on the Basement-Structure Survey form (3-5 hours per week or 0.71 hours/day). An exposure assessment of a 24-hour subchronic exposure was also evaluated. The exposure time for the evaluation of the upstairs chemical concentrations was assumed to be 24 hours/day because the actual time spent there is unknown. These exposure assessment calculations are provided in Appendix F.

Where the exposure assessment is lacking in site-specific data, EPA standard default exposures factors are used. The standard default factors are obtained from the RAGS Supplemental Guidance, "Standard Default Exposure Factors," Interim Final, March 25, 1991 and include:

- An inhalation rate of 15 m^3/day. (This represents a reasonable upper-bound inhalation rate for daily, indoor, residential activities.);
- An exposure frequency of 350 days per year. (This assumes approximately 2 weeks vacation per year away from home.);
- An exposure duration of 30 years. (This represents the upper-bound duration at a residence.); and
- A standard body weight of 70 kg for an adult.

4.4 Risk Characterization

The risk characterization estimates the incidence of any possible health or environmental effects based on the information developed from the exposure and toxicity assessments. Carcinogenic excess lifetime health risks and noncarcinogenic hazard indices were developed for three different chemical concentration estimates:

- The highest concentration level of each chemical detected during the study (Table 10A);
- The upper 95^{TH} confidence value of the arithmetic mean for PCE, TCE, c-DCE, and d-DCE (Table 10B); and
- Site-specific concentrations for the NE-1 residence (Table 10C).

Table 10A: Health Risk Results Using the Highest Chemical Concentrations.

Exposure Duration	Carcinogenic Excess Lifetime Risk*	Noncarcinogenic Hazard Index
12-Hour Chronic	1.2 x 10^{-5}	0.85
8-Hour Chronic	1.2 x 10^{-5}	0.57
24-Hour Subchronic	1.2 x 10^{-6}	0.17

Table 10B: Health Risk Results Using the Upper 95^{TH} Confidence Value of the Arithmetic Mean.

Exposure Duration	Carcinogenic Excess Lifetime Risk*	Noncarcinogenic Hazard Index
12-Hour Chronic	3 x 10^{-6}	0.35
8-Hour Chronic	2 x 10^{-6}	0.24
24-Hour Subchronic	2 x 10^{-7}	0.07

Table 10C: Health Risk Results Using Data from Residence NE-1.

Exposure Duration	Carcinogenic Excess Lifetime Risk*	Noncarcinogenic Hazard Index
Site-Specific Time Basement Chronic	4.3×10^{-7}	0.05
Site-Specific Time Basement Subchronic	1.4×10^{-8}	0.005
24-Hour Basement Subchronic	4.8×10^{-7}	0.17
24-Hour Upstairs Chronic	5.3×10^{-6}	0.58
24-Hour Upstairs Subchronic	1.8×10^{-7}	0.058

* 1×10^{-6} is 1 in 1 million

The U.S. EPA has stated in the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, October 1988 that an acceptable excess cancer risk should fall within the range of 1×10^{-4} to 1×10^{-7} (1 in 10 thousand to 1 in 10 million). The MDHES will determine what the action level will be for the LRY site. The results of the risk characterization show that both chronic and subchronic exposure to the airborne chemicals measured in the residences located near the LRY are within the range of 1×10^{-4} to 1×10^{-7}, using the assumptions given.

The Hazard Index does not exceed unity (1) for either the chronic or subchronic exposure durations, indicating that under present worst case conditions there appears to be no potential adverse health effects from short- or long-term exposures to the chemicals evaluated in this risk assessment by the inhalation route.

4.5 Uncertainties

The risk assessment process involves uncertainties associated with the assumptions provided in the risk assessment. The risk assessment, therefore, does not provide an absolute, quantitative measure of risk to public health and the environment due to potential exposure to site specific contaminants. Rather, the risk assessment serves as an indicator of potential unacceptable risk and can be used as an effective tool in the remedial management of the site. The uncertainties of the risk assessment conducted for the LRY are listed below.

- This risk assessment assumed that the highest chlorinated ethene concentrations measured from the indoor air study would remain constant through time. This assumes no degradation or dilution through natural environmental processes and there will be no source removal such as the source control activities now being implemented at the LRY.
- The exposure duration assumptions are all based on upper 95TH percent confidence values of the respective arithmetic means, which tend to overestimate the intake in the absence of site-specific data. Where site-specific data were available, the upper 95TH percent confidence value of the arithmetic mean was also calculated from the data and used in the exposure assessment. In addition, the upper 95TH percent confidence value of the arithmetic mean calculated for the time spent in the basement of the home was also multiplied by 1.5 to address potential future changes in the site-specific data.

The toxicity values provided in Section 4.2 are associated with a number of uncertainties. Some values are derived from animal studies and are extrapolations to predict human effects. The relationship between dose and response varies from one species to another. The dose response evaluations are typically performed utilizing high doses and therefore, low level exposures are not accounted for; and the toxicity values also contribute to the risk characterization process and are provided below.

- Risks may change logarithmically instead of arithmetically, increasing due to synergisms or decreasing due to antagonistic actions of multiple chemicals. This report assumes that no synergistic or antagonistic chemical interactions are present. The risks calculated for each chemical are summed to calculate the indoor air pathway risks presented in the tables. This method follows the guidance provided in RAGS.
- In the estimation of risk, uncertainties may increase or decrease risk, depending on the source of uncertainty. For example, extrapolation of the dose response of the animal studies and the development of the CSFs both contribute to the overall uncertainty.

4.6 Risk Assessment Conclusions

Based upon this preliminary risk assessment, immediate remedial actions in study area residences do not appear to be warranted at this time. However, the final decision regarding this issue will be made following the evaluation of this report, the conclusion of the risk assessment, and the setting of action levels by the MDHES.

Source control using soil vapor extraction was implemented at the LRY in early 1992. Source control activities will be accelerated during the spring and summer of this year with the offsite removal of the LRY sludges. The source control activities are being conducted to reduce or remove chlorinated ethene sources from impacting the ground water.